Maths 4 Life Sciences: Towards Developing an Innovative E-learning Resource

Report on a workshop and discussion forum held at Loughborough University on 17-18 January 2005.

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1. Introduction

The Higher Education Academy's Centre for Bioscience, in association with the Academy's National Teaching Fellowship Scheme funded this two-day workshop and discussion forum, which was hosted by the Centre for Engineering at Loughborough University. Fourteen colleagues from ten UK higher education institutions, the Centre for Bioscience, as well as the Director of the Educational Broadcasting Services (EBS) Trust came together to discuss (i) issues surrounding the mathematical competencies of bioscience undergraduates, and (ii) a proposal to develop an e-learning resource to support students in their acquisition and practise of core mathematical skills (see Appendix for a list of participants).

The main aims of the event were to:

1. facilitate discussion of key issues surrounding the perceived problems regarding mathematics in undergraduate life science curricula;
2. introduce participants to '**math**tutor' and **math**centre;
3. provide an opportunity for participants to gain hands-on experience of using '**math**tutor';
4. facilitate discussion of a proposal for the design and production of a similar (in terms of the technology used) learning resource for the life sciences, which may apply the paradigm of problem-based learning in providing mathematics support for undergraduate students;
5. provide an opportunity for participants to influence the subject-specific and maths content of this new and exciting learning resource and get actively involved in its production.

2. Defining the Maths Problem

The workshop got underway with a brief presentation by Vicki Tariq, at which she set the scene by providing the background to some of the issues surrounding the perceived decline in mathematical skills amongst university entrants. Participants then engaged in a number of activities which generated some lively discussion!

Group Therapy Session! (Activity 1)

(i) Participants were asked to write down **3 words or phrases** which summed up their **perceptions / feelings** of the maths knowledge and skills of undergraduate life science students.

Students described as ……	**Students' maths knowledge & skills**	**Academics**
• Innumerate • Fearful, phobic & disengaged with numeracy • Unwilling to try • Avoiding maths where possible • Over-relying on calculators • Lacking confidence in skills learned prior to HE • Lacking logical reasoning and a thoughtful approach • Lacking interest • Lacking understanding • Lacking the ability to apply their knowledge to problems	• Inadequate • Pathetic • Surprising • Worrying • Dangerous • Equivalent to top 1^{o} education level • Variable, often weak • Poor • Inflexible	• Feel sympathetic - students often didn't expect the demands • Are horrified at how little students recall and at the hints of poor teaching • Wish more could be done • Feel there's potential and hope • Recognise the diversity of problems amongst students of similar qualification • Feel an overview of the problem is lacking

(ii) Participants were asked to indicate a **particular event or experience** that had led them to the above conclusion(s).

- Being a research biochemist
- Talking to parents
- Talking to teachers
- Talking to academic colleagues
- Results of diagnostic tests (students unable to answer correctly using skills taught at GCSE level)
- Tutorials (working through problems with small groups of students; they often say they 'can't do' a question, but if you take them through step-by-step, they do have the skills and knowledge to answer but not the confidence and belief in themselves)
- Non-attendance or lack of engagement in maths-linked modules
- Increasing frequency with which students needed help with calculations involving dilutions/concentrations, and exploring their understanding
- Students using calculators to divide by 5
- Students' attempts at plotting graphs
- Individual teaching of weak students
- Too numerous to select one
- Teaching Sports Science basic maths – the students who spoke quite openly about the maths they were expected to do and couldn't
- Experiences when teaching students in level 1, especially during laboratory classes
- 7 years of teaching a 'friendly' maths course for biochemists at Oxford University
- Teaching quantitative physiology by making the students do calculations on the board
- Experiences teaching basic microbiology to level 1 students, particularly in practical classes, since the mid 1990s

(iii) Participants were then asked to list, in order of priority, **3 specific maths knowledge gaps or skills deficits** that were of particular concern within their discipline(s). Although rankings varied, there was considerable duplication in the topics identified.

Later in the afternoon participants were asked to add, in order of priority, any **further knowledge gaps or skills deficits** that were of particular concern within their discipline(s) and against each to provide an **example of its application** (Activity 4).

Their responses to both the above activities are summarised in the Table below.

Maths in the Life Sciences (Activities 1 & 4)	
Maths topics/skills	**Applications**
Comfort and confidence with handling numbers	Everything!
Basic numeracy/simple arithmetic	Everything!
Logarithms, powers, indices, exponentials	Scientific notation; Michaelis-Menten equation; Nernst equation; dilution series; scales; bacterial growth; half-life calculations for radioactivity; numbers of generation; handling very large and very small numbers; dose-response curves
Algebra/ re-arranging equations	pH calculations; biomechanics; concentrations of unknown from calibration line e.g. if you have an equation relating the transepithelial voltage and single channel conductance with current, you may know E_m and I, and want to calculation conductance, or E_m and G and want to calculate I (Physiology)
SI units; sense of the size of numbers; orders of magnitude; converting between units of measurement; areas and volume; accuracy and error	Converting within the metric system, or between systems (metric v. imperial); using a haemocytometer; deriving molar concentrations from g and ml; magnification and interpretation of

Maths in the Life Sciences (Activities 1 & 4)	
Maths topics/skills	**Applications**
	micrographs; leaf area approximation; observables v. parameters
Graphs / charts (data presentation & interpretation)	Calibration curves; linear v. linear; log v. linear; exercise testing (peak flow, etc); enzyme activity; testing for illegal drugs; human growth; blood glucose levels as a function of time; asymptomatic behaviour;
Fractions / proportions / percentages / ratios	Solutions and dilutions; body composition; diet composition; genetics; dilutions; wet mass / dry mass in growth analysis
Calculus Estimating / predicting / modelling	Population growth; spread of disease; epidemics; rates of change; transforming non-linear rates into straight lines; drug testing; radioactivity
Probabilities / risk	Evolution; death from disease examples; probability tree for a diagnostic test
Trigonometry	Calculating angles (e.g. petiole in relation to main stem)
Analytical skills (strategies to check whether answer is reasonable; relating answers to real life; using an alternative approach to the calculation or problem)	Measurement calculations; mols; energy of a photon; a lung volume greater than body volume; a heart rate > 1000 beats min^{-1}
Basic statistics (not to be included in project)	

3. Student Support Strategies (Activity 2)

Participants were asked to list up to 3 examples of strategies their module, degree, department/school, faculty and/or institution had implemented which support mathematics in the life sciences. Against one or more of their examples they were asked to indicate something: (i) positive and (ii) negative about the approach adopted.

Strategy	Positive Aspect	Negative Aspect
Diagnostic testing in 1st semester of 1st year: 5 key concepts; if score < 50% in two, referral to Maths Support Centre (Loughborough); if <50% in one, directed to relevant leaflet from Maths Support Centre	Central service with facilities and expertise to help students with problems; students who go praise the service, but say they would like more time with them	Students opt out and don't take up recommendations
Weaker students directed to simpler textbook to help support learning	Extra support without need for student to 'show weakness'	Not known how many use it or how useful it is except for the few spoken to
Lecture course / workshops	Seen to be doing something	Students still get lost
Distance learning	Very effective for slow / remedial learners	Students can get lonely
Maths centre	Excellent resource	Too few students use it
Maths Aid drop-in facility where students can get help with any maths problem on a 1:1 basis (UCLan)	Availability; individual	Students who most need help don't bother
Workbook which students work through at their own speed supported by academic staff able to give short time of 1:1 help; take tests as they	Improves competence	Level of improvement not enough

Strategy	Positive Aspect	Negative Aspect
complete each section		
Generic skills resource on the web – available to all students. Students advised to check out skills, discuss with personal tutor, who will guide them to this and other resources	Always available	Not seen as relevant; voluntary so students don't bother
'Skills' workshops	Provides help	Student dependent; 1st-years
'Skills' module for 1st-years	Covers a range of skills	Too little maths
Research methods for level 2	Includes statistics	Too late
Foundation science module (maths, physics and chemistry)	Covers wide range of ability	Not applicable to all students
Maths workshop – drop in sessions (caters for individuals and small groups)	Works well for those who attend	Doesn't reach all students
Computer Assisted Learning	Helps some students	Learning method doesn't suit all
Targeted provision	Stops those who don't need it being bored and reaches those who do need it	Difficult to organise
Diagnostic tests	Helps provide knowledge of skills deficits so that support can be tailored	Can be discouraging to the students so early in a programme
Drop-in maths support centre provided by mathematics department	Provides individual help	Not used much by science students
Use of in-house materials that define objectives with examples		
Regular self-assessment 'tests'	Marks awarded for completion, not performance	

4. Maths Learning Resources (Activity 3)

Participants, when asked to share information on maths learning resources they used, provided the following list:

Published Texts:

1. **Burton, Richard F. (1998)** *Biology by Numbers: An Encouragement to Quantitative Thinking*. Cambridge University Press, Cambridge. ISBN: 0521576989
2. **Burton, Richard F**. **(2000)** *Physiology by Numbers: An Encouragement to Quantitative Thinking*. Cambridge University Press. ISBN: 0521777038
3. **Cadogan, Alan & Ingram, Malcolm (2002)** *Maths for Advanced Biology*. Nelson Thornes Ltd., Cheltenham. ISBN: 0748765069
4. **Cameron, S. (1999)** *The Business Students' Handbook. Developing Transferable Skills.* London: Financial Times Pitman Publishing. ISBN: 0273630830. Provides an excellent guide to developing a variety of 'key skills', including general mathematical skills in Chapter 5.
5. **Cann, A. J. (2003)** *Maths from Scratch for Biologists*. Wiley, Chichester. ISBN: 0471498351
6. **Causton, David R. (1983)** A *Biologist's Basic Mathematics*. Hodder Arnold. ISBN: 0713128798
7. **Cornish-Bowden, Athel (1999, 2nd ed)** *Basic Mathematics for Biochemists*. Oxford University Press, Oxford. ISBN: 0198502168
8. **Currell, Graham (2005)** *Basic Mathematics and Statistics for Science*. John Wiley & Sons. ISBN: 0470022299.

9. **Foster, Peter C. (1998)** *Easy Mathematics for Biologists*. Taylor & Francis, London. ISBN: 9057023393
10. **Keck, Robert W. & Patterson, Richard R. (2000)** *Biomath Problem Solving for Biology Students.* Addison Wesley Longman Inc., San Francisco. ISBN: 0805365249
11. **Open University (1976)** *Genetics Course S299. Open University Press.* ISBN: 0335042805. Includes Mendel's original paper
12. **Phoenix, David (1997)** *Introductory Mathematics for the Life Sciences*. Taylor & Francis, London. ISBN: 0748404287
13. **Science and Technology in Society (SATIS)** *SATIS 16-19: File 3.* Association for Science Education (ASE). ISBN: 0863571387
14. **Torrance, James (1996)** *Problem Solving in Biology*. Hodder & Stoughton, London. ISBN: 0340664061
15. **Wassermans, K., Hansen, J. E., Sue, D. Y., Stringer, W. W. and Whipp, B. J. (2004, 4th ed)** *Principles of Exercise Testing and Interpretation*. Lippincott Williams and Wilkins. ISBN: 0781748763

In-house Booklets and Guides:

1. *Mathematics Booklet for New 1st-year Biochemistry and Earth Sciences Undergraduates*, written by Elspeth Garman, University of Oxford (2003), 20 pages. Students are required to work their way through this revision booklet prior to starting their degree programme. Contact elspeth.garman@biop.ox.ac.uk for further details and copy.
2. *Some Useful Mathematics: Basic Mathematics for Students Who Need to Use It,* written by Keith Gregson, University of Nottingham (2003), 50 pages. Contact Keith.Gregson@nottingham.ac.uk for copies.
3. *Study Skills: Data Handling,* written by Janet Clegg, St Mary's University College. Contact cleggjm@smuc.ac.uk for further information.
4. *Quantitative Physiology,* written by David Marples, University of Leeds. Contact D.D.R.Marples@leeds.ac.uk for further information.

Computer Assisted Learning (CAL) Programmes:

1. ***Key Skills Online*** (Intranet Support for Students, Eds Sue Drew and Louise Thorpe. Available from Gower Publishing)

   This is a web-based learning environment that provides a diagnostic 'skills check' and extensive guidance on the six 'key' skills (communication, working with numbers, ICT, working with others, problem-solving, and improving own learning and performance), as well as career management skills (http://www.qub.ac.uk/keyskills/).

2. ***math****tutor* (to be released by the EBS Trust in May 2005) A series of six CDs/DVDs covering a wide range of mathematics topics, from arithmetic to calculus.

3. ***'Maths for Microbiology'*** (QUB intranet support, produced by Fiona McGartland and Vicki Tariq)

   'Maths for Microbiology' - is a CAL tutorial that was originally designed to help students with the mathematics they encounter in a Level 1 'Microorganisms' module at QUB. It was produced in 1996, using Question Mark®, and is available to students across QUB, via its intranet. The tutorial provides students with the opportunity to test their knowledge of some fundamental mathematical concepts either before (in the 'Pre-test') and/or after (in the 'Post-test') working their way through the *'Maths for Microbiology'* tutorial. There are three files: (i) PRE-TEST, (ii) Maths for Microbiology, and (iii) POST-TEST. We always advised students to attempt the tests and tutorial in the order listed here. The tutorial was designed to be 'fun' to work through!

Internet Sites

There are some Internet sites that are linked to specific HE programmes:

1. A numeracy course for 1st-year pharmacy students at QUB at www.qub.ac.uk/pha/numeracy

2. University of Leicester, Alan Cann's web site, *Maths & Computers for Biologists*, provides online notes on numeracy and statistics. Available at: www-micro.msb.le.ac.uk/1010/default.html [Accessed 16 February 2005]

Others offer help with mathematics, e.g. in the form of on-line tutorials:

3. ***math****centre* at www.mathcentre.ac.uk (staff and student teach-yourself workbooks, help leaflets, refresher booklets, on-line diagnostic tests and practice exercises)
4. ***math****tutor* at www.ebst.co.uk/differentiation and www.ebst.co.uk/integration

Participants had the opportunity to gain some hands-on experience of using '**math**tutor'

Miscellaneous

1. Larson's maths cartoons (used by Elspeth Garman, University of Oxford)
2. A numbers game (for mental arithmetic) – devised by Elspeth Garman, University of Oxford. Contact elspeth.garman@biop.ox.ac.uk for further details.

5. Proposal to Develop an E-learning Resource: Some Key Points

Following their hands-on experience of using ***math****tutor*, participants were invited to discuss a written proposal to develop a similar (in terms of the technology and media used) e-learning resource to support mathematics in the life sciences. The ensuing discussion raised the following key points:

- The mathematics must be **set in context**
- Materials must **capture students' imagination**, **motivating them** to want to learn the mathematics inherent in the disciplines
- Provide **brief straightforward case studies/ problems/scenarios** (particularly at lower level and at start of discipline/topic)
- Provide opportunity for extensive **practise** - requires many brief case studies/examples of calculations. Early examples in particular should be short. Calculations/concepts must be repeated with many examples - possible to simply change numbers in some and to use same examples at different levels or for different disciplines (e.g. preparing a solution or dilution)
- Provide **constructive feedback** - this is vital so that students *learn* from their mistakes. Could also direct students to examples of most common mistakes and explain each
- **Good navigation** around the package so that students don't become frustrated when unable to move back and forth between sections

Some concern was expressed that with the 'case study' model students may have to deal with a new biological topic in addition to the maths, rather than just the maths on its own. In response to this concern it was emphasised that it was important that the mathematics was contextualised and that materials developed be integrated within a life science module and/or other support mechanism - at lower levels the e-learning resource certainly shouldn't represent the first time that students will have encountered either the life science or maths topics (e.g. they may have covered the topics at GCSE, AS or A2-level Mathematics).

It was also suggested that there should be reference or links to (or incorporating some materials from) ***math****tutor* and/or ***math****centre*.

6. Organization

Jim Stevenson (EBS Trust) explained what the roles and responsibilities of the EBS Trust and its academic partners would be, in the event of the proposal developing into a funded project.

ORGANIZATION OF THE PROJECT	
ACADEMICS' RESPONSIBILITIES	**BUILDERS' RESPONSIBILITIES (EBS Trust and new media contractors)**
Selecting topics & appropriate level – a long process!	Shooting and editing the video material and preparing animations outlined by academics

ORGANIZATION OF THE PROJECT	
ACADEMICS' RESPONSIBILITIES	**BUILDERS' RESPONSIBILITIES (EBS Trust and new media contractors)**
Scripting: preparing the outline/structure/storyboard of the case study and associated maths topics This is analysed and commented upon by others Someone is present during videoing to check content	Design and navigation
Supporting materials: creating, checking and monitoring materials at all stages	Publication
A LOT OF QUALITY CONTROL NECESSARY!	**OVERALL PROJECT MANAGEMENT**

Co-ordinating Team or Working Group

It is anticipated that there will be different levels of commitment from different individuals. A Co-ordinating Team/Working Group will initially comprise those from the January 2005 event who wish to become members and will be chaired/led by Vicki Tariq. It will be the responsibility of members of this team to decide upon the scope of this project, to bid successfully for the funding necessary to support the project, whether from one or a number of different funding sources, and to identify and invite appropriate supporting academics (i.e. writers and monitors) to participate in the project. As and when appropriate, additional members may be co-opted from amongst academics who have expressed an interest in this initiative but who were unable to attend the January event, the EBS Trust and its new media contractors, as well as any future funding oranization(s).

Writers

In addition, a significant number of academics from across the range of life science disciplines will be co-opted to help prepare the large number of case studies required; mathematicians will assist with the associated maths topics identified within specific disciplines

Monitors

A further group of academics will be responsible for monitoring and checking the quality and accuracy of all materials produced.

Project Management

Overall management of the project and funds will be the responsibility of the EBS Trust which has considerable experience and expertise in managing projects of this size and nature.

7. Funding

Cost: Estimated that it will cost approximately £100,000 to develop and evaluate a pilot DVD, perhaps dealing with a specific discipline within the life sciences or a specific topic (e.g. cell biology or genetics) that crosses several disciplines. It has been estimated that the remainder of the project will require a minimum of £500,000.

Potential funding organisations identified included:

Bioscience Organizations	HE Organizations	Government	Other
Biosciences Federation (incl. Institute of Biology)	HE Academy	HEFCE	Gatsby Foundation
Wellcome Trust	Joint Information Services Committee (JISC)	DfES	ESRC
Smith Kline Beecham		NHS/NHSU	NESTA
BBSRC			Nuffield Foundation

Time: The project would take 2-3 years to complete.

8. Suggestions for Titles

Participants agreed that the title should be **short and snappy** and avoid words/terms that life science students might find excessively intimidating.

Potential words/terms in a title	Intimidating or limiting words/terms
Math(s), biomath(s), numbers, data Calculations Tutor, coach, mentor, guru Help, guide Essential, core Skills Understanding, gist, handling	Mathematics Quantitative Analytical/Analysis Biosciences Biology

The top five titles below (in blue, but in no particular order) are currently the most popular among participants and a small sample of 2nd-year students from UCLan.

#1: *Calculations 4 …….. Sciences* (suggested by two 'A-level' Maths students because it avoids the dreaded 'maths' word)

#2: *Maths 4 ……. Sciences*

#3*: Understanding Biomaths*

#4: *Number Skills in …….*

#5: *mathguide 4 ……* or ***math****guide 2 ……*

e.g. ***math****guide 4 Life Sciences I, II, III, IV,* etc, OR ***math****guide 2 Cell Biology,* etc, OR

1. ***math****guide 4 Biological Sciences* (to cover agriculture, cell biology, ecology, genetics, microbiology, plant science, zoology)

2. ***math****guide 4 Biomolecular Sciences* (to cover biochemistry, biotechnology, food science, forensic science, molecular biology, pharmacology/pharmacy)

3. ***math****guide 4 Biomedical Sciences* (to cover anatomy, human biology, medicine, neuroscience, nursing, physiology, sports science)

Reasons: These resources may link better to ***math****tutor* and ***math****centre* if their titles have a similar style/structure. The example is similar to the style of the excellent series of books: *Practical Skills in Biology, Practical Skills in Environmental Science*, and *Practical Skills in Biomolecular Sciences*.

Alternatives on this theme: ***biomath****tutor,* ***biomath****guide,* ***biomaths****help* (may be read as *biomath shelp*!)

Maintaining 'math' (or biomath') in the title may help obtain funding from some organizations, e.g. Gatsby Foundation.

#6: *Working with Numbers in ……..* (rather long)

#7*: Numbers in ……..* (but what about 'Numbers'?)

#8: *Understanding Numbers in ……* (rather long)

#9: *Data Handling in ……* (this may imply that statistics will also be covered, which it won't)

#10: *Handling Numbers in ……*

#11: *Core Skills in Life Sciences* (but only mathematical skills will be covered), therefore *Core Skills in Biomaths* is probably better

#12: *Quantitative/Analytical Skills in Life Sciences* – long and possibly intimidating

#13: *Solving Numerical Problems in Biology*

9. Taking the Process Forward

1. The Co-ordinating Team is currently in the process of identifying potential sources of funding for the project

2. Apply for funding. This will involve preparing a formal and detailed proposal (incl. background literature, design and development of materials [incl. pilot materials], evaluation, etc)
3. Identify key participants and lead roles for all levels of activity.

APPENDIX

List of Participants

Name	Institution	Email
Janet Clegg	St Mary's University College	cleggjm@smuc.ac.uk
Barbara Cogdell	University of Glasgow	b.cogdell@bio.gla.ac.uk
Graham Currell	University of the West of England	Graham.Currell@uwe.ac.uk
Peter Foster	University of Central Lancashire	pcfoster@uclan.ac.uk
Elspeth Garman	University of Oxford	elspeth.garman@biop.ox.ac.uk
Keith Gregson	University of Nottingham	Keith.Gregson@nottingham.ac.uk
Paula Griffiths	University of Loughborough	P.Griffiths@lboro.ac.uk
David Marples	University of Leeds	D.D.R.Marples@leeds.ac.uk
Steve Maw	Centre for Bioscience, HE Academy	s.j.maw@leeds.ac.uk
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Chris Skidmore	University of Reading	c.j.skidmore@reading.ac.uk
Jim Stevenson	EBS Trust	jim@ebstrust.u-net.com
Vicki Tariq	University of Central Lancashire	vtariq@uclan.ac.uk
Mike Tribe	University of Sussex	miketribe2@ntlworld.com